COMPUTATION PROBLEM OF ELECTRICAL ENGINEERING

Vol. 1, No.1, 2011

INTELLIGENT POWER NETWORKS OF ELECTRICAL POWER SYSTEMS

Oleksandr Kyrylenko
Institute of Electrodynamics of NAS of Ukraine
kyrylenko@ied.org.ua

Abstract. Problems associated with the development of today's electrical power engineering are considered. Analysis of the concept "Smart Grid" and peculiarities of its development is made. Basic technological and technical components of the concept implementation have been identified. The problem of identification of the most acceptable decisions for Smart Grid platform realization in Ukraine with regard to those groundworks that found their implementation in power networks has been investigated.

Key words: intelligent power networks, electrical power systems, Smart Grid concept.

Introduction

Electrical power engineering is one of the branches that develops dynamically, and constantly performs technological retrofitting. Reliability and effectiveness of its functioning are ensured by creation of powerful energy interconnections with centralized generation, development of the networks of electric power distribution and control organization both generation and consumption. The time of rapid progress of electric power engineering is connected with the time when new and more powerful generating equipment was put into operation, when networks of electric power transmission were expanded, more powerful energy interconnections were created and control systems were improved.

However, there has recently appeared a necessity to correct the directions of electrical power engineering development. It is caused, on the one hand, by the further economic growth that is indissolubly related to the increase of the level of power consumption and increase of requirements to the quality and level of reliability of energy supply. On the other hand, it is caused by considerable negative effect of electric power engineering on the environment, by problems with providing reliability in the functioning of energy interconnections and creation of powerful energy equipment. To be more precise, there is a number of factors to consider. First, generation development due to the usage of traditional technologies results in the considerable deterioration of ecological situation and increase of fossil fuel consumption, and, accordingly, in the reduction of its resources and increase in price [1]. Second, there are new tendencies in generator design (transfer to the creation of power generating unit with the capacity up to 600 MVA [2], as 800-1200 MVA units have insufficient reliability and effectiveness of functioning). The third factor is the creation of power systems with distributed generation. Such systems are oriented towards a joint usage of powerful generative equipment and renewable energy sources functioning of which differentiates significantly [3]. In addition, it should be mentioned that in the electric power engineering the systems of control are imperfect that led to the increase of the accident rate in electrical power systems [4, 5]. And, finally, we should not forget about a great depreciation of the main and complementary electric power equipment and insufficient level of power networks development. The cited reflections showed the necessity of taking cardinal measures to solve the problems above. But such measures should not demand considerable single-stage capital investments; it should give real output relatively quickly and orient towards advanced manufacturing sciences. In this connection there was accepted a new ideology of electric power engineering development on the basis of Smart Grid concept in the USA and then in European Union (EU).

According to [1, 3, 6-9], technological platform Smart Grid anticipates the development of power networks that ensures effective and reliable functioning of electrical power systems (EPS). This is realized due to coordinated management and organization of two-way communications between the elements of power networks, power stations, accumulating sources and users. Smart Grid is supposed to be developed first of all for reliable and effective integration of power stations with renewable energy sources (wind, sun, small hydroelectric power stations and others with its badly anticipated working hours) in traditional power systems.

For the last years term Smart Grid has been treated as a concept of innovative transformation of electric power engineering. The basic principles of branch modernization were determined [6-9, 10, 11].

1. The branch modernization is realized by system and impacts all of its components – electric power generation, transmission and distribution, selling and dispatching.

2. Energy system develops as "internet-like" infrastructure that supports power, informational,

economic and financial interrelations between the subjects of energy market.

3. Electrical network is considered the main object of formation of new technologic basis which gives an opportunity to create new functional features of a power system that ensure the achievement of key goals. These goals are defined by all subjects of that process.

4. Formation of concept includes the whole work package – from the background research to the widespread introduction of innovations and it is conducted at the scientific, regulatory, technological, technical, organizational, informational levels as well as at the level of management.

5. Realization of the concept cares its innovative character and expects the transition to the new technological structure in electrical power engineering and in economics as a whole that is determined as economics of sustainable development.

Within the framework of the development of Smart Grid concept the various requirements of all interested parties are brought to the group of so-called key values of new electric power engineering. Such values are availability, reliability, economy, efficiency, organic connection with an environment [6, 12].

Relying on the indicated statements, the programs dealing with the development of Smart Grid concept are already accepted by many countries of the world. First of all it concerns the USA, countries of EU and China. As a prospect of development of the unique power system (UPS) in Russia the creation of the electric power systems with an actively adaptive network is considered [11, 13]. UPS in Russia is known to differ from others in considerable territory of the parallel work, configuration of electric networks and centralization of operative management of a greater part of electrical power engineering in the country.

The lighted up problems also refer to Ukraine, and that is why the formation of our own Smart Grid concept is obligatory. In addition, if the development of electrical power engineering of Ukraine is based on the old ideology, it will not be able to integrate either with Europe, or even with Russia, that is inadmissible. From our point of view, the closest concept for Ukraine is that accepted in the USA and presently positively perceived and utilized in Russia. It can be formulated as a concept of construction of the fully computer-integrated, self-regulated and self-renewing electrical power system (EPS), which has a network topology and includes all generating sources, highway and distributive networks and all types of electric power users, which follow the unique network of automated devices real-time. In general, the matter consists in creation of intelligent electric networks (IEN) of EPS. There is an expectation of conducting a complex of organizational changes, constructing new process models, involving new decisions in the branch of information technologies, as well as innovations in the sphere of creation of automated systems for technological process control (ASTPC) and reformation of controller's management. To a great extent the concept of energy alteration in Ukraine will be alike that of UPS alteration in Russia.

In Ukraine, taking into account its large power dependence the question of the development of renewable energy sources is getting special actuality. The old concept of power engineering development makes it practically impossible to connect many distributed energy sources to the Ukrainian IPS network. At the same time the creation of IEN only in sort will allow to solve the existing in Ukraine problems of power regions with their deficit of generation, «locked» capacities, and weak intersections. It should also be added that the technical decisions of electric network construction in Ukraine have a row of differences from those accepted in the world and some other legislatively normative base that also must be taken into account at the creation of Smart Grid concept in Ukraine.

Thus, if the indicated statements would be taken as a base for forming a way of development of energy in our country, we should remember that Smart Grid concept concerns all of IPS of Ukraine, from highway networks - to the users. Realization of the key requirements of construction of IEN EPS will be carried out by improvement of traditional and creation of new features of a power system. Thus, a number of features of electrical power engineering will get its development.

1. Self-renewing at emergency disturbances. A power system and its elements constantly support its technical state at the necessary levels by identification of risks, their analysis and transition from control when disturbed to preventing the network elements from being damaged.

2. Motivation of an active behavior of an end-user. The recipients of energy get a possibility to independently change a volume and user descriptions (level of reliability, quality etc.) on the basis of determination of the balance of queries and possibilities of the power system with the usage of information about the parameters of prices, volumes of generation, reliability of energy supply etc.

3. Resistance to the negative influences. Application of special methods that reduce physical and information vulnerability of all components of EPS and promote both prevention and its rapid renewal after failures in accordance with the requirements of power safety.

4. Providing the reliability of energy supply and quality of electric power in different price segments. Transformation of a system-oriented approach into client-oriented.

5. The usage of various types of power-stations and devices of electric power storage (a distributed generation). Optimum integration of generating and accumulating capacities in a power system, connection by standardized procedures of the technical joining, implementation of «micropowersystems» (Microgrid) at a user level.

6. Reformation of power and energy markets up to inclusion of the end user in their activity. Free access to the markets of electric power of the so-called «active user» and distributed generation in order to increase the effectiveness and efficiency of a retail segment.

7. Optimization of asset management. Transfer to the remote monitoring of functioning of capital stocks in real-time; integration of such monitoring into the corporate control system for the increase of work efficiency, improvement of operating processes, repair, replacement of equipment and, as a result, cutting of general costs.

It is considered that the application of Smart Grid technology should provide the optimum distribution of power flows of electrical network, diminishing of losses in it, rapid coordinated response in emergencies, and possibility of formation of a unique power system of both large power-stations and modern renewable energy sources. Efficiency of the technology is determined by automation of making decisions on management; increase of efficiency of normal and emergency modes management. All of it is shown on the indexes of efficiency of energy companies – quality and reliability of electric supply in condition of optimization of own charges and needs quite a new level of informatization. The quantity of measureable signals and telecommunication interfaces requirements will broaden substantially. One of the substantial consequences of Smart Grid technologies distribution will be that in course of time all industrial and domestic energy receivers will be able to co-operate in an information network, become guided and will execute the functions of measuring its electric energy and power consumption.

In Tabl. 1, 2 the comparative analysis of traditional and intellectual EPS is showed. Thus, tabl.1 enlightens a difference on separate indexes, whereas tabl.2 provides characteristics of realization of a number of technological processes.

The selection of hardware plays a decisive role in the realization of Smart Grid concept. On the whole we may talk about five groups of basic technological areas within the bounds of which the realization of the concept of IEN construction is provided [1,3,10,14,15].

The first group includes intellectual data transmitters, checking and measuring means, devices of account and proper devices. This means the devices for measuring the parameters of a network by normal, prefault, emergency and postfault operations, means of control of objects condition, which ensure operation of the systems of monitoring, control, diagnosis and management and also intelligent meters.

Table 1

№	Characteristics and indices	Traditional	Intelligent
1.	Electric power supply	Centralized generation and distri-bution	Distributed generation and inherent sources of energy
2.	Network topology	Radial	Network
3.	Maintenance management	Diagnosis and scheduled report	Remote monitoring and on-condition maintenance
4.	Organization of supervisory control	System-oriented, automated and manual	Client-oriented, real-time, ASTPC
5.	Reliability	Local protection systems and automatics, renovation – virtually by hand	Adaptive distributed protection systems, autoreduction and sectioning
6.	Information-measuring systems and communication	Local pickups and meters, user information flow	Distributed, intelligent, information flows – bidirectional
7.	Situation assessment	According to fact	Forecasting and prevention of occurence
8.	Electric power market	Capacity and energy market	Energy market, capacity market refusal

The second group involves information-gathering and –transmission systems, which contain distributed intelligent devices and analytical tools for communications support at the level of power system objects that operate real-time. It is operating means which realize the functions of gathering, control and monitoring, diagnosis and outputting of recommendations, organizations of co-operation with corporate systems and operating personnel. For example, it is possible to select the information-measuring systems (SCADA), systems of measuring the parameters of processes in progress (AMOS), distributed generation monitoring systems (DGMS), distributed system of demand monitoring and control (DMCS) etc.

The third group includes intelligent automated systems of objects control (ASTPC), integrated systems

of organization of measuring and account of electric power consumption, telecommunications systems on the base of various communication links and system of visualization, system of transient state monitoring (WAMS), distributed systems of protection and emergency automation (WAPS) etc.

Table 2

№	Technology	Characteristic
1.	Generation	Integration of renewable sources in EPS, distributed generation using energy storage systems, intelligent protection systems, diagnosing and management.
2.	Transmissio n	New technologies and means of control, monitoring and mode control (FACTS, PMU, WAMS, WACS etc.). Intelligent adaptive systems of protection and automatics (with automatic resumption of supply).
3.	Objects	ASTPC in corpora.
4.	Distribution and consumption	Network structure, distributed systems of control, protection and automatics (with resumption of supply and sectioning). Intelligent systems of energy control and accounting, adjustment by electricity consumption and management by loading (including alarm conditions), functions of "active user" – adjustment by electricity consumption.

The fourth group is compiled from active load-bearing elements and technologies, such as flexible alternating current transmission systems (FACTS), technologies of reactive power control, control of distributed generation and energy storage, and also new cable equipment. In addition, to this group we refer also force hardware, which count more than 20 types of various devices for monitoring reactive power and voltage, network parameters, short-circuit current limiting, electric energy storage, transformation of current (alternating current into direct current and vice versa), switching equipment of new generation etc.

And the fifth group is a unifying constituent that includes systems and information technologies which provide data and information exchange for those facilities functioning included into four groups and the electric energy market.

The main thing in financial realization of an intelligent networks concept is its technical and technological platform. This is technologies and devices of small and mean power generation, which include renewable energy sources. The usage of such sources in power system results in transition from the centralized generation to the distributed one that influences to a considerable extent almost all characteristics of EPS with intelligent networks. For Ukraine this question is the one of future, though the first groundwork's have already found its application. However at present the alternative sources can not compete with hydrocarbon and atomic power sources without corresponding normatively legal support.

With regard to further development of IPS of Ukraine, it is connected, first of all, with realization of new approaches at which a leading hand is assigned to introduction of new technical decisions and technologies. At the same time, it is necessary to select active elements (fourth group of devices) which allow changing network characteristics or realizing electric power transformation in order to optimize of modes of operation flexibly. The matter is the increase of carrying capacity, in-process loss decrease, support of corresponding indexes of electric energy quality etc. For example, as it was estimated, an application of FACTS equipment allows increasing the carrying capacity of corresponding intersections to 20% and decreasing in-process losses to 40%.

A new generation of facilities of information-measuring systems, automation, and automatics, which work real-time and allow solving problems of management of electrical power objects (ASTPC), power supply control and management, relay protection and emergency automation, monitoring and diagnosis of technological equipment condition, referred to the next group. The purpose of equipment functioning that belongs to this group is the realization of operation modes of electric systems and networks in accordance with the terms of electric energy market operation, warning and minimization of emergency situations consequences.

And eventually, we should mention information-technological equipment, systems and IP provision of control centers of EPS, which coordinate operation modes of the electric networks taking their new possibilities into account. We mean the usage of distributed generation, active network equipment and substation and station automation. Actually, a new technology of EPS control will be realized on the principle of real time taking the features of electric energy markets operation into account.

Power electronics occupies one of the key positions in the process of Smart Grid ideology realization and IEN creation. It concerns the tasks of providing adaptive power elements functioning, solving problems of energy-savings and power efficiency. Power electronics makes a power system not only more flexible in management and more resistant to different kinds of

disturbances, but also allows considerably reducing the electric power losses during the operation with underloading (optimization of power transmission ways), reducing capital expenditure due to possible introduction of lower powers [11, 12].

Thus, the development of electrical power engineering in extensive way, that is a way of its power increase due to the usage of new and even more perfect equipment, does not have a prospect for a number of reasons. Firstly, for technological reasons. Today networks cannot successfully integrate heterogeneous separated energy sources and modern traditional generation sources, in addition, even in perfect enough EPS of leading countries regularly take place serious system failures with the losses in hundreds of millions and billions of dollars. Secondly, for economic reasons. At the present development state of electrical power engineering the favorable conditions for a valuable use of electric energy market advantages can not be created.

All these problems concerns Ukraine as well, and that is why the acceptance of the concept of Smart Grid development is obligatory for us. In addition, there is severe problem of energy-savings and power-efficiency in Ukraine. It is impossible to solve this problem without intelligent networks introduction, in particular, without intelligent meters, power supply control systems, without perfect systems of electric drive monitoring etc. The development of renewable and alternative sources of energy, taking into account our large enough power dependence on other countries, is very important for Ukraine.

In Ukraine, certain favorable conditions for realization of Smart Grid concept have already been created. What concerns the scientific support, the potential of Ukraine is sufficient to solve almost all problems [14, 15-17]. The researches into the application of superconductor inductive energy stores (SCIES) to EPS seem to be perspective [20]. Calculations which showed the possibility of the usage of SCIES as a device for dynamic resistance and for the increase of the level of EPS survivability by realization of the process of emergency power-station selection on the local loading area were made. The ranges of energy intensity of stores needed for the solution of these problems are determined by way of example.

The increase of electric power transmission economy provides the strengthening of controllability of alternating current lines with monitoring of the streams of active and reactive power. To such facilities we can refer the systems of flexible management on the basis of devices of power electronics (FACTS), static controlled compensators, asynchronized synchronous generators which are used as reactive-power sources [16-20].

At the same time in Ukraine there is only a part of off-the-shelf scientific and technical solutions, and there is practically no organization of hardware production. And power equipment is our tender spot. Of the 20 names of these devices we produce only a few of them (controlled shunt reactors, synchronous and asynchronized compensators, phase-controlled transformers and some other). There is a tendency to introduce nonflammable power and control cables into power-stations and substations. Lately in such cases a new type of cables and wires with a synthetic isolation is widely used.

What concerns an information engineering and technologies, Ukraine is almost ready to solve all the problems. The primary and secondary pickups and devices have already been created and now they are produced for power engineering purposes from the model to operational; the information systems on basis of «Regina» complex which solve almost all modern problems of electrical power engineering informatization (monitoring of all modes, control and diagnosis), have been already created and are widely implemented. On basis of «Regina» complex there were created the local networks of objects, automated system of substations control and control of stations distributed devices, including those with 750 kV of voltage, automation of the South part of power system of Ukraine, complexes for operative-dispatch management of power systems and IPS of Ukraine [16-17], and there were made others important scientific, technical and technological world level decisions, necessary for creation of intelligent networks. Especially it should be mentioned of creation and introduction of «REGINA-CH» complex for precision measuring of voltage and frequency vectors in a power system with highly accurate time synchronization of these measuring by the satellite system GPS. On its basis the creation of modern technology and monitoring system (WAMS) and also *on-line* technologies of electric power transmission management is begun (WACS) [12].

The first step on the way of transition of electrical power engineering of Ukraine to realization of Smart Grid concept and creation of IEN EPS must be clarification of Strategy of the electrical power engineering development in Ukraine up to 2030 taking the indicated statements into account .

References

1. World Energy Outlook 2009. International Energy Agency (IEA), Paris 2009.

2. Fedorenko G., Kensytskiy O.: Hydroenergetyka Ukrainy, 2009, 1, 7.

3. European Smart Grids Technology Platform: vision and Strategy for Europe’s Electricity Networks of the Future. European Commission, 2006.

4. Energetik, 2005, 8, 9.

5. Energetik, 2005, 8, 2.

6. Grid 2030: A National Version for Electricity's Second 100 Years. Office of Electric Transmission and Distribution United State Department of Energy, July 2003.

7. Lachsetal W.R.: IEEE Transmission on Power Systems, 1996, II, 1.

8. A vision for the Modern Grid. The National Energy Technology Laboratory, March 2007.

9. Smart Power Grids – Talking about a Revolution. IEEE Emerging Technology portal, 2009.

10. Kobets B., Volkova I.: Energorynok, 2010, 3, 66.

11. Shakaryan Y., Novikov N.: Energoekspert, 2009, 4, 42.

12. Kovalev V., Ivakin V., Fotin V.: Elektrichestvo, 2006, 9, 8.

13. Dorofeyev V., Makarov A.: Energoekspert, 2009, 4, 28.

14. Kyrylenko O., Zhuykov V., Denysyuk S., Rybina O. Systemy sylovoyi elektroniky ta metody yikh analizu. Tekst, Kyiv 2006.

15. Kyrylenko A., Prikhno V., Chernenko P.: Nauka ta innovatsiyi, 2008, 6, 12.

16. Stogniy B., Butkevich A., Zorin Y., Levkonyuk A., Chizhevskiy V.: Tekhnichna elektrodynamika, 2008, 6, 52.

17. Stogniy B., Kyrylenko O., Pavlovskiy V.: Tekhnichna elektrodynamika, 2009, 2, 63.

18. Allayev K., Fedorenko G., Ostapchuk L.: Tekhnichna elektrodynamika, 2009, 2, 58.

19. Bondareva N., Grobovoy A.: Elektricheskiye seti i systemy, 2007, 3, 9.

20. Avramenko V., Aristov Y., Vasetskiy Y., Mazurenko I., Chernenko P.: Tekhnichna elektrodynamika. «Problemy suchasnoyi elektrotekhniky», 2008, III, 43.

ІНТЕЛЕКТУАЛЬНІ ЕЛЕКТРИЧНІ МЕРЕЖІ ЕЛЕКТРОЕНЕРГЕТИЧНИХ СИСТЕМ

О. Кириленко

Розглянуті проблеми, що пов'язані з розвитком електроенергетики в сучасних умовах. Проведено аналіз концепції Smart Grid та особливостей її розвитку. Визначені основні технологічні та технічні складові реалізації цієї концепції. Досліджена проблема визначення найбільш прийнятних рішень для реалізації платформи Smart Grid в Україні з урахуванням тих напрацювань, що знайшли впровадження в електричних мережах.

Oleksandr Kyrylenko – born on 05.20.1950. Academician of NAS of Ukraine, director of the Institute of Electrodynamics of NAS of Ukraine, head of department of design of power objects and systems. Main direction of scientific activity – the development of basic theory and development of scientific principles and methods of creation of the integrated information systems of electric networks.

The results of his research work are discribed in numerous publications (over 300), including 14 monographs.